

Sub-microradian Pointing for Free-space Optical Communications

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ABSTRACT

NASA/JPL has been developing technologies for a novel and unified approach to point a laser beam with sub-micro-radian precision for optical communication systems. The approach is based on using high bandwidth inertial sensors to compensate for jitter excursions caused by spacecraft vibrations. This novel use of high bandwidth inertial sensors enables the implementation of laser communication links anywhere within the solar system (and even beyond).

A widely accepted scheme for accomplishing the detection, tracking, and pointing function (required in free-space optical communications) is to split a fraction of a received uplink beacon signal and direct it onto a focal plane array (FPA) detector. The motion of the focal spot on the FPA is tracked to accurately point the downlink data signal to the Earth receiving station. For deep space links, the historical approach to compensate for spacecraft vibrations and dead-band excursions has been to close a high-bandwidth pointing-control-loop using optical-tracking (> 500 Hz). But, this method required the use of a separate uplink beacon (laser or Earth image). However, studies have shown that using these optical-tracking references become limited in tracking bandwidth in deep space applications, because of the small amount of signal reaching the spacecraft. Our recent analysis and simulations indicate that, by augmenting the current architecture (celestial optical tracking) through the use of high rate inertial sensors (gyros, accelerometers, rate sensors), the tracking and pointing performance will be improved to the sub-micro-radian level.

Analogous to an attitude and control subsystem, the spacecraft motion is measured using the gyros, and this measurement is used to correct instrument pointing. Optical updates are then made infrequently to correct for the low frequency inertial sensor drift. Since optical measurements are no longer needed at the rate required to close the pointing compensation loop, such a scheme allows for a significant reduction of the required tracking update rate. Furthermore, this technique enables the use of dimmer stars (and/or a dim uplink laser). Therefore, combined with a low rate, high accuracy optical tracker, these inertial sensors can be successfully used to compensate for jitter, to close the control loop and to point to a receiving station with sub-micro-radian accuracy. This presentation will cover innovative hardware, algorithms, architectures, techniques and recent laboratory results that are applicable to all deep space optical communication links.

Key Words: Optical communications, acquisition, tracking, pointing, inertial sensors.